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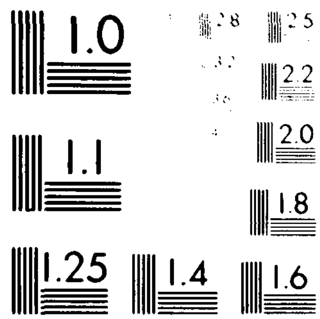

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

COMPOUND APPLICATION OF MICROWAVES AND INFRARED

by

Zhou Hongren

FOREIGN TECHNOLOGY DIVISION

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COMPOUND APPLICATION OF MICROWAVES AND INFRARED

by Zhou Hongren

Microwaves and infrared each have their strong and weak points but can they be a "compatible pair", be used in combination and be mutually beneficial? In recent years, fire control systems in modern fighter planes, besides those provided with interception firing radar, are frequently equipped with an infrared search tracking device.

In 1800, the British astronomer William Herschel, who had discovered Uranus, conducted an interesting experiment. He placed a sensitive thermometer in a spectroscope and obtained a solar spectrum. Curiously, when the thermometer changed from a violet to red color the thermometer reading increased. Even more interesting was that when it was placed outside the red light, the temperature rose even higher. The highest temperature was in the range of 0.8 microns (1 meter=10^6 microns). This important discovery brought mankind into a new era of the understanding and application of infrared rays.

Following this, after one hundred years of fundamental

research, infrared rays have gradually been applied in industrial and scientific research. The first application of infrared technology was in military affairs during the First World War. At that time, there was no radar but they used an infrared locator to probe for light bombers at a distance of up to one and a half kilometers.

After the Second World War, following the quick development of radar and electronic technology, automatic control materials and technology, infrared technology also entered a new period of fast development and was praised by people as opening up new scientific and technological frontiers.

One of the most effextive uses of infrared technology in military affairs is in the fields of probe tracking and missile control which include various styles of infrared search tracking devices.

In the family of electromagnetic spectrums, microwaves and infrared are like two close brothers. As regards the objective of probing fixed locations, radar without a doubt is a latecomer that has surpassed its predecessor. Why do we still want to develop infrared search tracking devices? This is because infrared also has other special characteristics:

1. The passivity in work principle. Theoretically, any substance with a temperature higher than absolute zero (minus 273 degrees centigrade) radiates infrared rays. Because of this, any target has the capability of being discovered. Following the development of high altitude/high speed and low altitude/high speed airplanes the radiant heat on the envelope is even stronger which is advantageous for infrared technology.

2. Its resolving capabilities and fixed position precision is high. These two factors create an inverse ratio with the wavelengths and infrared wavelengths are over one thousand times shorter than radar wavelengths.

3. It is not easy for people to jam it. The infrared device works passively and does not have side valves. Because of this, it is not easy for an enemy to discover and jam it.

4. Its structure is simple, use convenient, volume small, weight light and power consumption small.

However, infrared rays also have their drawbacks. Most important is that when used at low altitudes they are effected by weather conditions (clouds, fog, rain etc.) and under natural conditions interference is relatively great, thus making all weather properties bad. Moreover, the problem of

using infrared rays for passive accurate range finding still exists in probing. Satisfying the demand for a fire control system is also a flaw that must be remedied.

Microwaves and infrared each have their strong and weak points but can they be "a compatible pair", be used in combination and be mutually beneficial? This is a question that has been discussed by related engineers and technicians for the last twenty odd years and results have already been attained in practice. At present, there are three types of combined utilization methods: follow up synchronization, combined antenna and compound control.

Follow Up Synchronization

The principle of this combined utilization method can be seen in chart 1. The systen is divided into the two conditions of "radar alone" and "radar and infrared combined". When it is in a radar alone work condition, relay J_2 has no movement and contacts 1 and 2 are connected. When searching, the antenna search command produced from the search command production device passes relay J_1 and goes on to the angle tracking circuit causing the radar antenna, based on demand, to search in space. When it reaches its target, the echo goes through the receiver and after being amplified is sent to the indicator.

When tracking, relay J_1 has movement, there is the breaking of the search command, contact 2 and 3 are connected, the angle error command amplified by the receiver is sent to the angle tracking circuit and throughout drives the antenna aiming it at the target.

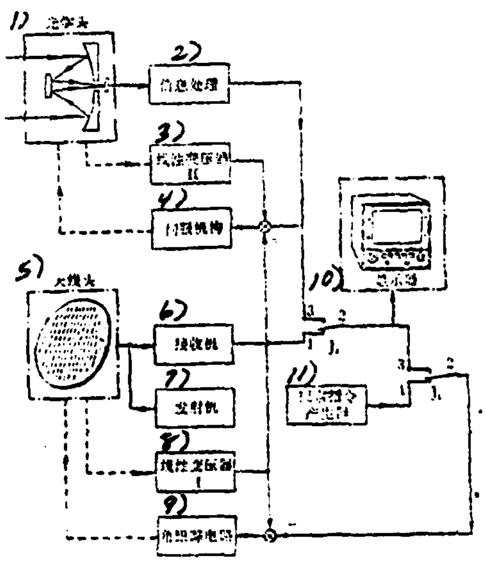

Chart 1 Radar/Infrared Synchronized Follow Up System

Key: 1. optic head

2. information handling

3. linear transformer II

4. servo mechanism

5. antenna head

6. receiver

7. emitter
8. linear transformer I
9. angle tracking circuit
10. indicator
11. search command production device

When the radar is jammed and is incapable of working, we can use the radar/infrared joint system. At this time, relay J_2 has movement and contacts 2 and 3 are connected. When searching, the command put out by the search command production device still drives the radar antenna to search. Yet at the same time, when the output voltage of the radar antenna axis angle position's linear transformer I sent into the infrared device is compared to that of the output voltage of the infrared axis angle position's linear transformer II, the error voltage produced is used to control the infrared optical head servo mechanism causing the optic axis and antenna axis directional to coincide and synchronically search. When the optic head scans the target, after the received target command is amplified it is sent to the indicator. When tracking, relay J_1 has movement and the target angle error command measured by the infrared device passes through J_1's contacts 2 and 3 and is sent to the radar angle tracking circuit and drives the antenna to be directed toward the target. At the same time, the voltage of the antenna's angle position, still based on the method of searching, is sent

into the infrared device causing the optic head to also be aimed at the target.

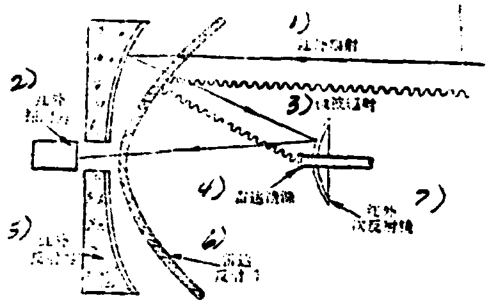

Chart 2 Sketch Chart of Radar/Infrared Combined Antenna

Key: 1. infrared radiation

2. infrared probe

3. microwave radiation

4. radar feed

5. infrared reflector

6. radar reflector

7. infrared secondary reflecting lens

Obviously, this is a synchronized follow up system whereby the infrared optic head follows the radar antenna head and maintains synchronization with the antenna head. This is very much like two brothers watching an airplane, wherever the older brother points the younger brother watches and necessarily

watches to see whether or not the older brother is pointing accurately. If it is not accurate, he must ask older brother to correct his own directional and only stops when he is accurate.

The principle of this kind of system began to develop to maturity and be extensively used during the 1960's. Representative of this was the American naval F 4B airplane which used the APQ 72 radar and the AAA 4 infrared device to create a synchronized follow up system. This type of infrared device had a finding distance in fighters of up to 30 kilometers.

In the 1970's, the superior American naval F 14 fighter, apart from having its nose fitted with AWG 9 guidance control radar, also had its nose equipped with an infrared search tracking device. There has already been development in the use of follow up synchronization. Its essential uses are:

1.When the radar ceases effectiveness due to breakdown or jamming by an enemy, the infrared device acts as a substitute for the radar. Among the information surveyed is included rough distance information which is used to provide guidance for launching an "Undying Bird" or "Sidewinder".

2. The optic head and antenna head can be synchronized or unsynchronized. When radar searches in cerain airspace, the infrared device can search in other airspace so enlarging the system's airspace search.

3. Because the infrared device operates within a shorter wavelength, for all of the targets seen by radar, the infrared device can be used to distinguish single targets.

Combined Antenna

The basic use of the follow up synchronized method can be said to be antijamming. This method, from the point of view of aviation use, needs to find another place to fit the infrared optic head besides the front of the airplane because it creates a negative influence on the airplane's aerodynamic performance. This is a drawback. Because of this, early, at the end of the 1950's, there were people who had probed the simultaneous use of infrared rays and microwave energy to make the directional device information source, the so called "dual system". In this system, the signal handling, indication and servo mechanism all used infrared and microwaves and the key sections were only a "radar/infrared combined antenna".

The aim of the combined antenna is to seperate the infrared

radiation from the microwaves so that it can use a different method to carry out receiving. The specific methods are quite numerous. Chart 2 is a schematic diagram of one type of combined antenna. The radar reflector uses highly conductive mesh material for manufacture and the mesh hole size is smaller than the radar wavelengths. It completely reflects the microwave energy of the target's echo to be received by the radar feed and 80 to 90 percent of the infrared radiation is able to penetrate. The infrared reflector is fitted behind the radar reflector and the infrared energy that comes from the target is reflected to a secondary reflecting lens and again reflects to be received by the infrared probe. This can handle the microwave and infrared energy in the signal handling circuit, raise the indication and be used for range finding and tracking.

Compound Control

Rocket control radar is the eyes of an airplane. It must not only be able to see far but must also be able to see accurately. If it has accuracy, then it can effectively control weapon launchings. Because of this, since the appearance of tracking radar, the essential problem has been the improvement of radar tracking precision. The radar/infrare compound control method can not only antijam but can also improve tracking

precision.

The angle tracking systems of tracking radar are all closed cycle feedback control systems. After the error of the antenna microwave system which sensitizes the antenna relative to the line of sight (radar/target continuity line), it is amplified by the receiver and sent to the angle tracking circuit drive antenna which decreases the existing error of the antenna axis and the line of sight. This way, relying upon the error of the imput measurement (line of sight angle) and modulated measurement (antenna angle) there is carried out a controlled feedback system. In principle, the error cannot be eliminated because if there is no error there is no control. Furthermore, because of the system's unavoidable inertia, the more the line of sight angle changes (the more acute the target mobility), the greater this type of error is. In chart 3, the section below the dotted line is the radar closed cycle control system.

In the compound control system, besides the original closed cycle control, an open cycle control is also introduced. For the infrared search tracking device's independent tracking target, after the target's (line of sight) movement information is measured in the tracking target process and handled, it is added to the radar's angle tracking circuit to help the operation

of the radar antenna allowing the antenna axis to keep pace with the movement of the line of sight even faster. This then constitutes the radar antenna's open and closed cycle compound control system. In chart 3 the section above the dotted line is an open cycle passage. If this type of system is designed well, it can decrease quantitatively the dynamic hysteresis error of the radar tracking target. Moreover, the system is open and closed independently, which do not interfere with eachother, its design is simple and it is very easy to regulate. When the radar is jammed, the open cycle passage can still control the radar antenna's directional target. Naturally, when used for antijamming operations it does not need other changes.

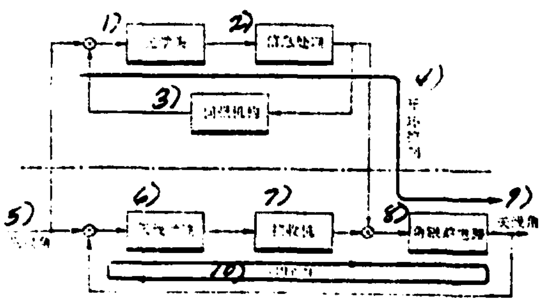

Chart 3 Radar/ Infrared Compound Control System

Key: 1. optic head

2. information handling

3. servo mechanism

4. open cycle control
5. line of sight angle
6. antenna microwaves
7. receiver
8. angle tracking circuit
9. antenna angle
10. closed cycle control

Briefly, the combination of infrared technology and radar is a type of probing and tracking target technical method which is without a doubt very important in military affairs. Its significance is also especially great in modern electronic warfare.

Illustration by Wen Chengcheng

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